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Design and Development of the Neuronal Time Series Analysis (NTSA) Workbench

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The NTSA Workbench is a software system for storage, retrieval, analysis, visualization and sharing of neurophysiological data, including massive multi-channel data sets and model simulations. Substantial progress has been made toward development of an integrated system, consisting of: a) a database for organized storage and efficient search and retrieval of data meeting specified criteria of interest; b) high resolution digital brain atlases for integration of neuroanatomical information with time series neuronal data; c) the time series data protocol (TSDP), a standard for representation, transfer and analysis of time series neuronal data, and; d) a suite of flexible and intuitive tools for data analysis and visualization, as well as a programming library for development of TSDP-compliant tools that are inter-operable within the research community.

Current work of the project is focused on the digital brain atlas component of the NTSA Workbench. A high resolution digital brain atlas is the core of the NTSA system. A systematic solution has been designed and is now under active development. The solution consists of: a) an automatic image pre-processing program; b) an automatic atlas construction program; c) an atlas post-processing program; d) an image query program. The raw data are sequences of 2D brain sections prepared by cryosectioning. The automatic image pre-processing program prepares a clean image set for the atlas construction program. The atlas construction program renders the image set into a 3D digital brain atlas. Exceptional efficiency and accuracy are required of this program due to the high resolution and complexity of the data set. A novel image registration algorithm is being developed on the basis of a hybrid non-linear optimization method and a new objective function called minimum entropy of bad prediction (MEBP). This algorithm improves upon traditional pair-wise registration algorithms by taking account of long-range information across multiple sections in the image set. After the atlas construction, the resulting digital atlas is polished for better visual effect. A high resolution digital brain atlas can potentially occupy Gigabytes to Terabytes of storage space. In order to improve efficiency, a hierarchical structure and a near-lossless compression algorithm are being developed. The hierarchical structure is an improved version of the octree data structure and the near-lossless compression algorithm is extremely fast compared to existing methods. Finally, the image query program utilizes the digital atlas to support the upper level 3D spatial database. A 3D spatial database engine is being incorporated with the existing relational database to integrate the neuroanatomical and neurophysiological times series data. Primitive queries (e.g., point, range, spatial join, relational) are integrated in different combinations and orders of execution to form high level queries that are intuitive to neuroscientists. The suite of atlas-related and spatial database programs is not data set specific; rather, they can be applied to many similar digital atlases.

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